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ting down aught in malice. He was, I believe, above most men, one who can stand the test. His faults are patent. One cannot read him long without forgetting them in admiration of his nobly simple merits. I have said that I believe his chance of survival better than that of any other contemporary American man of letters. I trust I have shown why. In the first place, he has recorded in a way as yet unapproached the homely beauties of New England nature. In the second, he accepted with all his heart the traditional democratic principles of equality and freedom which have always animated the people of New England. These principles he uttered in words whose simplicity goes straight to the hearts of the whole American people. Whether these principles be ultimately true or false is no concern of ours here. They are the principles which must prevail if our republic is to live. And in the verses of Whittier they are preserved to guide posterity in the words of one who was incapable of falsehood.

1893.

BARRETT WENDELL.

ASSOCIATE FELLOWS.

WILLIAM FERREL.

It is particularly fitting that our Proceedings should contain some memorial of WILLIAM FERREL, for it was in this community that he first found a broad scientific association, after a boyhood of unrecognized genius and a manhood of mental isolation. It was only at the age of forty that he found companionship with men of ability like his own, and then he was so retiring by disposition and habit that he could but slowly embrace the wider opportunities opened to him.

A memoir of Ferrel by his associate, Professor Cleveland Abbe, was read before the National Academy in April, 1892, and appended to this appreciative review of his life we find a brief autobiographical sketch prepared a few years before his death, and a list of his published writings. This memoir may be referred to for fuller information, as I shall here attempt only to emphasize certain prominent features of his character, and certain of his greater accomplishments.

In recalling the work of the four great meteorologists of our country, — Redfield and Loomis, Espy and Ferrel, — the first two of them

are seen to have been characterized by a preference for inductive methods, and the other two by a greater use of deductive methods. I do not mean to imply that any one of these able men was so unbalanced as to be illogical in his studies, and follow only one method to the exclusion of the other; but that they had natural leanings one way or the other, as most men have. The greater fund of material embodied in our modern weather maps was fitly used by Loomis, much in the same manner as Redfield had used the scattered records of storms half a century earlier; the greater accuracy of the results gained by Loomis is a measure of the greater fulness of material for investigation, rather than an indication of a difference between the two men. On the other hand, much as Espy was led to his understanding of storms through a mental invention, a theory, ingeniously based on physical laws, so Ferrel was led to a generalization concerning the circulation of the entire atmosphere from a full appreciation of the laws of motion, rather than from any acuteness of observation. The consequences deduced from his theory far outstripped the knowledge of his time and profoundly affected the further progress of the science. His earlier studies of the tides were carried on in the same way. His work always illustrated the power of the mind to conceive and combine relevant facts with a view to explaining them legitimately, yet with little recourse to direct observation or experiment for himself. It is noticeable in his autobiographical sketch that Ferrel seldom makes mention of observation or experiment as holding a significant part in his early or more mature studies. As a boy he played with geometrical problems, spending weeks together over a single one; the diagrams which he scratched on the barn door with the prong of a pitchfork were only so many convenient records of the conditions of his problems; but he tells nothing of making mechanical toys, which hold so large a place in the youth of experimental philosophers. When only fifteen years old, he struggled over the prediction of eclipses, but the facts he dealt with were supplied chiefly from Farmer's Almanacs; nor did this study seem to awaken in him a wish for means of investigation with astronomical instruments, but only a keen-desire for more books.

It is sad to think how limited were his opportunities in his youth. He was born in Bedford (now Fulton) County, Pennsylvania, on January 29, 1817. When he was twelve years old, his father moved across the narrow arm of Maryland into Virginia, and there the boy went to school two winters, the schoolhouse being a rude log cabin, with oiled paper instead of glass in the windows. His last school teacher took him through arithmetic and the English grammar. He was too diffi-

dent to ask his father for money with which to buy books,—too difficult even to confess his wish for books; but he worked in harvest time, and earned enough money to buy Park's Arithmetic, in which he learned something of mensuration. He continued to buy all the books he could afford, a very few, and studied them most diligently. In winter evenings he had only firelight to read by, or sometimes a pale tallow candle; in the summer, he would study while at work in the barn, attacking and solving all the problems that the books supplied. This plain living on his father's farm was not unlike that of thousands of other boys; but his unquenchable thirst for knowledge carried him out of the narrow surroundings in which his neighbors remained. We must always sympathize with the difficulties under which Ferrel struggled in his youth, and at first thought we should wish he might have had an easier life; but who can say whether the lessons of successful endeavor against all obstacles were not essential for his later development as an original investigator? His isolation turned him towards original methods of thought; and this originality and independence mark all his later work. The few distractions in his early life must have allowed the development of the perseverance with which he worked upon anything that took his attention, never giving it up until he could make some advance in it, or until he satisfied himself that he could not do so.

At the age of twenty years, having earned some money by teaching near home, he went to Marshall College, at Mercersburg, Pennsylvania. On exhausting his funds, he went home again and taught for two years more, then going to Bethany College in Virginia, where he was graduated in 1844. This closed his education as far as instruction from others was concerned, at the age of twenty-seven. For the next fourteen years he taught school, mostly in villages in Missouri, Kentucky, and Tennessee. It must be of these lonesome years that he speaks in the closing paragraph of his autobiography: "Much of my time has been wasted, especially the earlier part of it, because, not having scientific books and scientific associations, I had often nothing on hand in which I was specially interested."

Yet it was in these lonesome years that Ferrel had the good fortune of finding a copy of Newton's "*Principia*" in the hands of a village storekeeper in Missouri. While in Kentucky, he sent to Philadelphia for Laplace's "*Mécanique Céleste*"; and when in Nashville, he came upon Airy's *Essays* on the "*Figure of the Earth*," and on "*Tides and Waves*." Living alone with these great leaders, he carried their work on further, and made his own impress on the study of the ocean and the atmosphere.

Not until 1853, when Ferrel was thirty-six years old, does he mention any publication of his studies; but in that year he sent his first scientific article to Gould's "Astronomical Journal," and this marks the beginning of his association with scientific men. Four years later an invitation came through Dr. Gould from Professor Winlock, then Superintendent of the Nautical Almanac, for Ferrel to take part in the computations for that work. A year was needed to close his school connections in Nashville, and in 1858 we see him settled in Cambridge, with time and opportunity to gratify his studious tastes. Our image of him at that time must be clad in simple attire. He brought with him from his isolated life many homely peculiarities. From his awkward manner, one could hardly have imagined the mental power that placed him so high above most of his fellows. A gentle diffidence still possessed him, and even several years later his timidity prevented him from reading an important article on the tides before this Academy until he had carried it to several successive meetings.

He never pressed forward his views, but let them take such place as their own value should give them. He never sought for office, but was invited to fill responsible positions in the Coast Survey and the Signal Service. In these congenial surroundings, he carried on his earlier studies of the tides and the atmospheric circulation, and thus a well deserved fame gradually grew around him.

It is Ferrel's impress on meteorology that strikes me as most extraordinary, not only from the explanations that he gave to its facts, but from the new methods that he introduced into its study. Before him no one had made any considerable mathematical analysis of the motions of the atmosphere; and it was not for a number of years after he had opened this new line of investigation that European masters of mathematics followed him in it. Ferrel began this work at Nashville, where in 1856 he saw a copy of Maury's "Physical Geography of the Sea"; a suggestive work from its collection of facts, but sadly in need of correction for its erroneous theories. As in his other studies, Ferrel did not begin here by observation of the winds, but by searching for a sufficient explanation of the facts observed by others. The story is one that should be familiar in our scientific history, for it illustrates as few others can the real quality of scientific investigation. In Ferrel's hands, meteorology was not simply a routine record of observations, not simply a vague suggestion of theories. The broadest generalizations from world-wide observations were brought into harmony with the universal laws of motion, and as a result Ferrel's theory of the atmospheric circulation left all its predecessors far behind. The more

general facts concerning the prevailing winds of the world had been accumulated and were presented with much force by Maury; and at the same time, various theories had grown up to account for the facts. These theories all had two general principles in common; first, that there must be a convectional circulation between the equator and the poles; and second, that the motions thus excited must be deflected by the earth's rotation. As commonly stated, it was understood that there must be high pressure at the poles, where the air is cold, just as there is low pressure around the equator where the air is warm; and as stated by Dove, who at the time of Ferrel's entrance into the science was its leading authority, the currents from the equator to the north pole must flow from the southwest, while the return currents from the north pole to the equator must flow from the northeast. Ferrel perceived the essential incompleteness of this view of the subject. He first showed that the prevailing explanation of the effect of the earth's rotation was incomplete, and then, applying this important element in its proper measure, he introduced the idea of a rearrangement of atmospheric pressures in consequence of convectional motions. This great principle may be followed all through Ferrel's theories of cyclones and tornadoes, as well as through his theory of the circulation of the atmosphere as a whole. Its quantitative introduction into meteorology seems to me to be Ferrel's greatest achievement.

Ferrel showed that the convectional interchange between the equator and the poles must resolve itself into two great circumpolar whirls, one in either hemisphere; that in the greater part of the whirls the currents must move eastward, the trade-wind belts being the only considerable regions of westward motion; that, in consequence of the circumpolar whirls, the expected high polar pressures must be reduced to relatively low pressures, especially in the southern hemisphere, where the disturbing effects of continental interruptions are least; and that the air thus held away from the poles must be found in the tropical belts of high pressure, then coming to be recognized as great atmospheric features. It is not too much to say that the introduction of this theory has made a new science of meteorology. Ferrel's mark is permanently imprinted upon it.

We are apt, in reviewing a step of advance like this, to imagine that it was made at a single stride; but such was certainly not the case here. The theory of atmospheric circulation grew slowly in Ferrel's mind, and several years passed before it was fully developed. During its progress, Ferrel's efforts were constantly directed towards quantitative estimates of forces and results. This feature of his work is strikingly

illustrated in his theory of tornadoes, where from beginning to end he follows out a definite sequence of processes, beginning with reasonable conditions as to the distribution of temperature and moisture, and showing in the end that these might produce the extraordinary velocities seen in tornado winds. The definite quality of this work is most reassuring, in contrast with the vague speculations commonly prevailing about these peculiar storms.

After resigning from his professorship in the Signal Service in 1886, Ferrel spent his later years peacefully with his relatives near Kansas City. He died on September 18, 1891, at Mayfield, Kansas, and was there buried.

1893.

W. M. DAVIS.

FREDERICK AUGUSTUS GENTH.

FREDERICK AUGUSTUS GENTH was born at Waechtersbach, Hesse Cassel, May 17, 1820. After leaving the Gymnasium at Hanau, in 1839, he studied at the University of Heidelberg, and afterward under Liebig at Giessen, then under Bunsen at Marburg. He received his Doctor's degree in 1846, and was then for three years assistant to Bunsen and Privat-Dozent. As a student at Heidelberg, he at first took up the study of conchology, and published at least one paper on that subject. Later he became interested in what finally proved to be the work of his life, chemical mineralogy; and after his removal to the United States, in 1848, he quickly took a very prominent place among mineralogists. In 1846 he first studied the compounds of cobalt with ammonia, and laid the foundation for all which has been done since. In this country he again took up the subject, and with Dr. Wolcott Gibbs made an elaborate investigation, which was published in the "Smithsonian Contributions to Knowledge," Vol. IX. After a very active and busy life as an analytical chemist in Philadelphia, he became, in 1872, Professor of Chemistry and Mineralogy in the University of Pennsylvania, which place he held until 1888, when he returned to his work as a chemical expert, still keeping up, however, his active interest in his favorite study, chemical mineralogy, and continuing to publish papers on that subject almost up to the time of his death, the last appearing in January, 1893. The list of Dr. Genth's published papers is a very long one, and embraces nearly one hundred titles. Among others, it includes Reports on the Mineralogy of Pennsylvania and North Carolina. Mineralogy owes him the discovery of about twenty new species. His long and useful life terminated on